



RoboCup: Humanoids as a test bed for Measuring Performance

Minoru Asada
Adaptive Machine Systems
Osaka University, JAPAN
August 13th, 2002
PerMIS-02@NIST

RoboCup 2002 Fukuoka/Busan

- The Largest RoboCup since 1997
 - ◆ 1004 participants, 188 teams from 30 nations around world, and about 1000 media people.
 - ◆ About 120,000 visitors during one press day and four open public days
- The first humanoid robot league
 - ◆ 13 teams from 6 nations
- ROBOTREX (Robot Trade & Exhibitions)
 - ◆ 50 companies, universities, and institutes

Outline of my talk

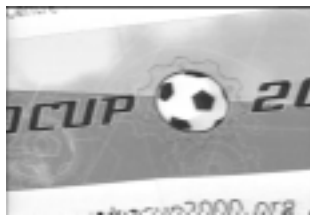
- RoboCup
 - ◆ Purpose, Current State, and Issues.
- Technological issues towards final goal: Humanoid league
 - ◆ Levels of autonomy
 - ◆ One leg standing, walk, PK, and free style
 - ◆ Future issues

What's RoboCup?

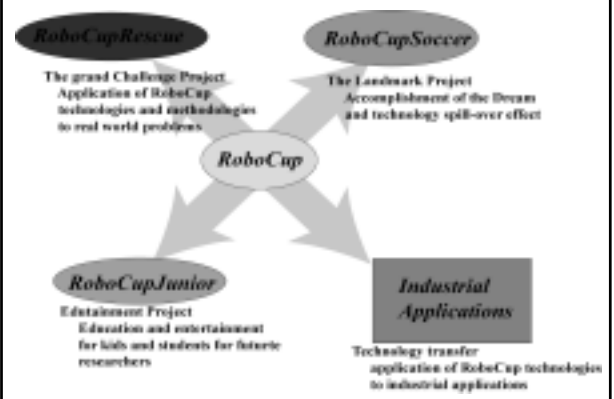
An attempt to foster intelligent robotics research by providing a standard problem



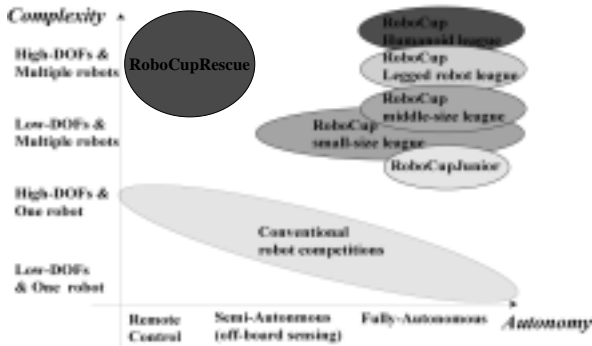
Video Clips



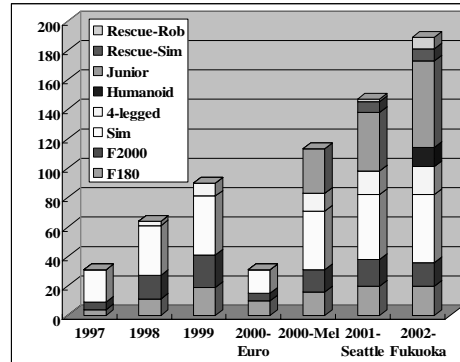
What's RoboCup?



RoboCup and ROBOCON



Number of Teams



Why RoboCup? (I)

■ Landmark Project:

- ◆ to set a goal high enough so that a series of technical breakthroughs is necessary to accomplish the task
- ◆ this set of technologies should form the foundation of a next generation of industries
- ◆ widely appealing and exciting

Ultimate Goal →

To beat the human world cup champion team by a team of 11 humanoids

Why RoboCup? (II)

■ Standard Problem:

- ◆ a systematic approach to promote research using common domain, soccer!

■ Comparison with “Chess Problem”

	Chess	RoboCup
Environment	Static	Dynamic
State Change	Turn taking	Real time
Info. accessibility	Complete	Incomplete
Sensor Readings	Symbolic	Non-symbolic
Control	Central	Distributed

Research Issues in RoboCup (I)

- Mechanical design for individual robots
- Robust Sensing, especially, vision (object discrimination and tracking)
- Self-localization and map building
- Control Architecture
- Communication

Research Issues in RoboCup (II)

- Multi-agent systems in general
- Behavior learning for complex tasks
- Combining reactive and modeling approaches
- Real-time recognition, reasoning, planning, and action execution in a dynamic environment
- Cross modal association (Sensor fusion)
- Strategy acquisition
- Cognitive modeling in general

Divisions of RoboCup

- **RoboCupSoccer**
 - ◆ Simulation: Coach, Visualization
 - ◆ Real robot: Small, Middle, Legged, and Humanoid
- **RoboCupRescue**
 - ◆ Simulation and real robot
- **RoboCupJunior**
 - ◆ Soccer, Dance, and Rescue

Soccer Simulation League

- Low cost, Stamina model, 11 v.s. 11, limited perception, broadcasting



- Secondary Domain → RoboCup-Rescue

Soccer Simulation League

- Teamwork
- On-line learning
- Coach competition
- Visualization



Real Robot Leagues

- Small Size league: A table tennis table, an orange golf ball, and global vision..
- Middle Size league: 3X3 table tennis tables, an official soccer ball, and local vision..



Real Robot Leagues (cntd.)

- Legged league: Sony AIBO Type robots, 4 on 4.
- Humanoid league: Four classed according to the size. One leg standing, walk, PK, and free style



Small-size league

- 1997~ Global vision:
- Perception: Sharing global information → reliable and real-time detection of multi mobile robots and ball.



Small-size league (cntd.)

- 2000, field: wooden → fabric
- 2002, enlargement of the field to encourage the team plays.



Middle-size league

- Fully distributed system, but centralized control is OK!
- Evolution from individual behavior to team plays.



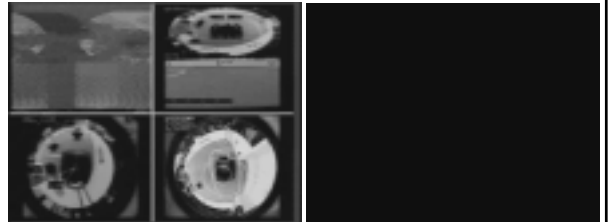
Middle-size league (cntd.)

- Global reconstruction by LRFs (C. S. Freiburg, Germany)



Middle-size league (cntd.)

- 1997~ 5 on 5 Footsul-4 ball
- 2000~ 4 on 4 Footsul-5 (official ball)
- Omni-directional vision, Reactive behavior, and social ones.



Middle-size league (cntd.)

- Holonomic Vehicles: Omni-directional movement



Middle-size league (cntd.)

- 2002~ No walls
- Quick motions
- Team plays



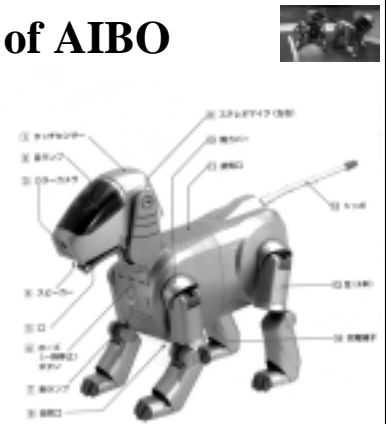
Legged league

- Programming competition based on the same platform
- 1998: exhibition (Osaka U., CMU, Paris-VI)
- 1999~: Official league (2m x 3m, 3 on 3)



Structure of AIBO

- energy
- sensor
- computer
- actuator
- mechanism



Legged league (cntd.)

- Various kinds of behaviors: Ball handling
- Teamwork: social behavior based on vocal communication



Legged league (cntd.)

- 2001~: New platform
- 2002~: 3m x 4m, 4 on 4, wireless communication



Humanoid league

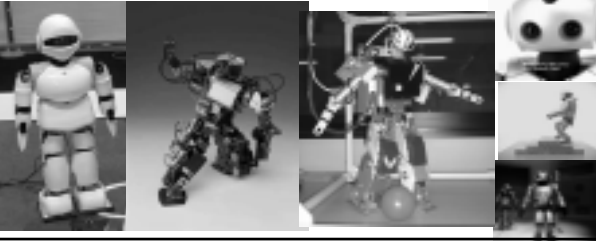
- 2002: the first humanoid robot soccer.
- 4 kinds of size: 40cm, 80cm, 120cm, 180cm
- Performance factor towards fully autonomous humanoid robot: Platform, power supply from outside, remote brain, human control
- Japan (5), Sweden (3), Singapore (2), New Zealand, Australia, Denmark



Why humanoid robot?

- One extreme application: test-bed for brain science.
- Current application: entertainment, pet robots.
- Another extreme application: practical use in our daily life??? → HRP by Japanese government.





```

graph LR
    subgraph Taskwork_Behaviors [Taskwork Behaviors]
        D1[Density Kick]
        P1[Pass a ball]
        R1[Run, Jump, and Turn]
        K1[Kick to desired direction]
        K2[Kick a moving ball]
        K3[Kick a stationary ball]
        C1[Change Speed]
        R2[Run]
        J1[Jump]
        T1[Turn]
        K4[Kick]
        OF[Object following]
        OT[Object tracking]
        OR[Object recognition]
    end

    subgraph Teamwork_Behaviors [Teamwork Behaviors]
        A1[Advanced teamwork team]
        S1[Strategic Planning]
        R1_1[Real-Time Planning]
        L1[Learning]
        H1[Highly sensitive situation awareness]
        C1_1[Attention to Coach's Command]
        A2[Auditory Scene Analysis]
        S2[Separation of Speech and Noise]
        SR[Speech Recognition]
    end

    D1 --> A1
    P1 --> A1
    R1 --> A1
    K1 --> A1
    K2 --> A1
    K3 --> A1
    C1 --> A1
    R2 --> A1
    J1 --> A1
    T1 --> A1
    K4 --> A1
    OF --> A1
    OT --> A1
    OR --> A1

    A1 --> S1
    A1 --> R1_1
    A1 --> L1
    A1 --> H1
    A1 --> C1_1
    A1 --> A2
    A1 --> S2
    A1 --> SR
  
```



- These factors were either used
 1. as penalty factor in the walking the time that was multiplied by them or
 2. as handicap (in penalty kicking the score was divided by them).
- ◆ They are working quite well (with regard to the above stated intention) and will certainly prefer the more autonomous robots but will also allow for semi-autonomous ones if their performance is much better than that of the autonomous ones. No changes needed.

Challenges: stand on one leg

- This is definitely no problem for most of the humanoid robots or it shouldn't be one while it is one for humans! It is a wonderful entry if the audience is also involved in this. It was done in Fukuoka by asking everybody in the audience to perform this challenge together with the robots.



Challenges: walking

- A round trip of humanoid walking along the way of five times its height.
- Every touch of a human during the walking gives a penalty which is linearly increasing: 20 sec/1st touch, 40 sec/2nd touch, 60 sec/3rd touch etc.
- Champion:
 - ◆ Nagara (Japan)
 - ◆ 81,64, and 61 seconds
 - ◆ 3.29 (p/f: 1.0)
- Second:
 - ◆ Robo-Erectus (SG)
 - ◆ 209, 109, and 183 secs.
 - ◆ 4.932 (p/f: 1.2)



Challenges: Penalty kick

- Total behavior coordination with walking, one leg standing, kicking, and balancing.
- The physical height of the striking robot was used to determine the distance between ball and striker while the measurements of the goals were only available for the two categories (40 cm and 80 cm height).



Challenges: Penalty kick (cntd.)

- First, to give the striker a realistic chance we introduced a 5 sec latency after the starting whistle before the goalie may start to walk towards the ball to reduce the angle which could be used to score a goal.
- Second, the line of the goal area was used a strict demarcation line to avoid the collision.
- The was so light that it often went astray due to small uneven parts in the field.



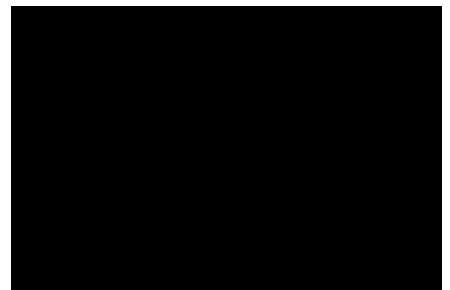
Challenges: Penalty kick (cntd.)

- First, to give the striker a realistic chance we introduced a 5 sec latency after the starting whistle before the goalie may start to walk towards the ball to reduce the angle which could be used to score a goal.
- Second, the line of the goal area was used a strict demarcation line to avoid the collision.
- The was so light that it often went astray due to small uneven parts in the field.



Challenge: free style

- Honda Asimo's example performance and digest from humanoid league.



Humanoid league: photos



Humanoid league: issues

- Performance factor: what values and how to apply?
- Stand on one leg: difficult to decide real time sensor feedback or open loop. Introduction of disturbance to check it.
- PK: from PK to 2 on 2!
- Free style: A test bed for humanoid research in general



Materials and Basic Components

- Surface Materials
 - ◆Soft, Embedded-sensory systems
- Frame Materials
 - ◆Light Weight
- Power Supply
 - ◆45 min x 2 + PK, etc.
 - ◆Weights and Safety
- Energy Saving Architecture

Materials and Basic Components

- Actuation Systems
 - ◆Current Motor-Gear system is too fragile
 - ◆Robust Parallel System is necessary
 - ◆Artificial Muscle
- Mechanical Design
 - ◆Joint systems, etc.
 - ◆Totally new design?

Basic Control Issues

- High Performance Mobility
 - ◆Basic Walking is accomplished
 - ◆Run and Jump
- Behavioral Robustness
 - ◆Can it safely fell down and stand up again?
- Behavioral Complexity

Sensory Systems

- Vision and Touch
- Auditory System
- Other Sensing Systems
- Sensor-Fusion
- Sensory-Motor Integration

High-level Cognitive Systems

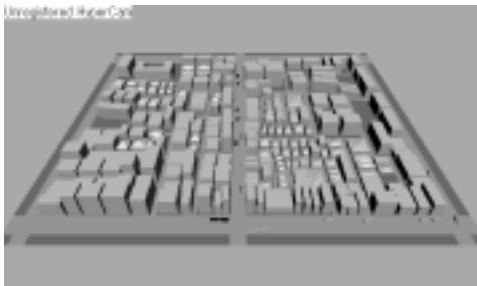
- Strategy Planner
- Learning
- Brain and Cognitive Science



Performance Measure with human

- Simulation league: computer team has got wins from human teams since 1997!
- Small size league: Human won until 1998, but no more since 1999.
- Sony AIBO league: robot team won!
- But, human teams have not got used to operate robots. What happened if they learned more?

RoboCupRescue Simulation



RoboCupRescue Simulation (cntd.)

500 x 500 m region in
Nagata Ward, Kobe City

Multi-layered human interface
with information filter



RoboCupRescue Real robot

- Evaluation of cooperation deployed in three stage rescue situations by NIST



RoboCupJunior



Future Issues

- Road Map towards the final goal: set up Milestones.
- Humanoid league: regulations



Future events

- Spring, 2003: regional events: Japan Open, German Open, US Open
- July, 2003: The seventh RoboCup at Padua, Italy
- July, 2004: The eighth RoboCup at Lisbon, Portugal



Acknowledgement

- RoboCup Federation,
- NPO RoboCup Japanese Committee
- Humanoid Chair: Prof. Dr. Thomas Christaller

<http://www.robocup.org/>

